

Reproductive ecology of the black-headed goanna *Varanus tristis* (Squamata: Varanidae)

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Abstract

The black-headed goanna, *Varanus tristis*, oviposits in October and November in the western Great Victoria Desert; the eggs are laid in a hole that the female digs in the ground. Neonates hatch toward the end of summer. Body colour and pattern of neonate *V. tristis* differ appreciably in the western Great Victoria Desert from adults, and changes to the adult pattern after a couple of months. Clutch size for *V. tristis* is best predicted from body mass, although there is also a significant relationship between clutch size and snout-to-vent length. An inter-specific regression equation for the *Odatria* subgenus is a much more accurate predictor of clutch size for *V. tristis* than a regression equation that includes data for goannas of other subgenera. Fat bodies of males decrease in size during December and January then increase during February and March; they are largest during September and October. Combined testis length decrease from approximately 11% of snout-to-vent length (SVL) during the breeding season in early summer to 5% of SVL in February.

Introduction

Relatively little is known about the breeding biology of the black-headed goanna *Varanus tristis* (Pianka 1971, 1986, 1994; Christian 1981; Broer & Horn 1985; Eidenmüller 1989). The breeding season is from September to October (Pianka 1971), and mean clutch size is approximately ten (James *et al.* 1992; Pianka 1994) but nothing has been reported on oviposition sites. There are two reports of *V. tristis* being bred in captivity (Broer & Horn 1985; Eidenmüller 1989).

This paper reports on the breeding behaviour of *V. tristis* in the western Great Victoria Desert, an oviposition site, variation in neonate body colour and pattern, the effect of SVL and body mass on clutch size, and seasonal cycles in testis and fat body size.

Methods

Observations on breeding behaviour were made during a larger study of activity areas and daily movement patterns for *V. tristis tristis* during the breeding season in the western Great Victoria Desert (Red Sands, 28° 12' S, 123° 35' E). The site is a complex mosaic of sandridges and interdunal flats with a vegetation of spinifex (*Triodia basedowii*), marble gum trees (*Eucalyptus gongylocarpa*), mallee trees (*Eucalyptus concinna*), acacia (*Acacia aneura* and others) and other small bushes and grasses. Location and daily movements of twelve *V. tristis* were monitored between 11 September and 8 November, 1995, in the western Great Victoria Desert using miniature radio-transmitters attached to the side of the base of the monitor lizard's

tail or surgically inserted into their abdominal cavity. One female *V. tristis* became gravid and laid eggs during this period.

Notes were maintained of evidence of courtship and breeding behaviour, *e.g.* males following scent trails, pairs together and hole digging activity. Spoor were also used to determine movement patterns. We also dug up one nest and removed eggs to hatch in an incubator. The incubator was maintained at about 29 °C and the eggs were placed in a mixture of vermiculite and water at the ratio 1:1 based on mass. This enabled us to measure neonate size and estimate incubation time.

Clutch size, maternal body mass and SVL of gravid females were recorded from an examination of 24 *V. tristis* captured opportunistically since 1967 in the arid interior of the Great Victoria Desert. Lengths of fat bodies were recorded for 63 males and 37 females captured since 1967 in the same general area. The combined length of testes is reported for 62 males.

Results

A male and a female *V. tristis* were found one behind the other in a hollow log on 15 November 1978. This male's testes measured 13 mm and 14 mm and the female contained 8 shelled eggs in the oviducts. On 30 October 1990, a mating pair was found together in a marble gum tree, the female had sperm exuding from her cloaca. A male *V. tristis* was seen lying on a female *V. tristis* under a spinifex bush on 1 October 1995 and both lizards were found in a hole in the ground on 2 October 1995. There was no evidence to indicate this hole had been dug by these *V. tristis* (*i.e.* no fresh scratchings). Other female *V. tristis* were seen in holes, or were seen digging holes on 13, 14, 24 and 26 October 1995. All females captured with a male had a white powder stain on the dorsal surface of



Figure 1. White powder stains on the dorsal surface of a female *V. tristis* during the breeding season and dorsal colour pattern.

their pelvic area, generally between their hind legs and mid-way up their backs (Fig 1).

One female *V. tristis* (mass 210 g, SVL 235 mm) was seen digging a hole in the base of the stump of a dead (burnt to ground level) marble gum tree on 17 and 18 October 1995. This *V. tristis* was again seen at the hole on 21 and 22 October 1995 when it back-filled the hole suggesting that it oviposited about 21 October 1995. Eggs were located in the burrow about 20 cm below ground surface. The female had burrowed down inside the hollow trunk and then dug through an underground hole in the dead tree trunk that would have been just large enough to get its body through. Eggs were deposited in a junction between a dead root and the basal bole of the dead gum tree. An initial attempt was made to excavate the nest chamber on 7 November 1995 but the eggs could not be found. Disturbance to the soil near the eggs may have damaged two eggs, described below to have hatched prematurely. Ten eggs were excavated from the nest on 21 January 1996; one of the eggs was desiccated and failed to develop. The other eggs were returned to the laboratory and incubated at about 29 °C. Two eggs hatched on 3 and 5 February; they appeared to be premature, as the hatchlings were small [3.2 g, SVL 67 and 68 mm, total length (TL) 163 mm]. These two neonates died within 24 hours of hatching. The remaining seven eggs hatched between 12 and 15 February, an incubation period of 114 - 117 days; these hatchlings were 4.3 g (\pm SD 0.31) and had a SVL of 72.7 mm (\pm SD 5.12), and a TL of 181.7 (\pm SD 11.54) and grew rapidly. SVL increased by 40% in the first 17 weeks of captive life, compared with 30% for *V. eremius* and 18% for *V. brevicauda* during a similar period in captivity (Thompson, unpublished observations).

As occurs in many species of *Varanus*, neonate *V. tristis* have a markedly different colour and pattern from adults (Bennett 1993, 1996). Adults in the western Great Victoria Desert have a dark grey-to-black head, neck, forelegs and most of the tail. The back has a fine reticulum of elongated black-centred red-brown circles (Fig 1). The proximal end of the tail is ringed with greyish-white flecks that fade in larger individuals. In contrast, neonate *V. tristis* from this site have a dark grey head with a broad black stripe through the eye. From the neck to about half way down the tail, the body is encircled by rings of closely spaced,



Figure 2. Body pattern of neonate *V. tristis* from the western Great Victoria Desert.

small, white-to-yellow dots (Fig 2). Fore- and hind-limbs have rings of less closely spaced, small, white dots. This colour pattern changes to that of the adult form during the first two months of life.

We examined 24 *V. tristis* with either enlarged yolked ovarian eggs or shelled eggs in their oviducts. Mean clutch size was 9.8 (\pm se 0.57), mean SVL of gravid females was 246.6 mm (\pm se 4.13) with a minimum SVL of 199 mm. Mean body mass of gravid females was 203.9 g (\pm se 10.9) with minimum mass being 86 g. Combined (left and right) testes length and combined fat body length as a proportion of SVL for 63 males and combined fat body length for 37 female *V. tristis* are shown in Figure 3. There is a significant difference in combined testis length as a proportion of SVL (ANOVA, $F_{7,55} = 9.86$, $P < 0.05$), and combined fat bodies length as a proportion of SVL (ANOVA, $F_{7,55} = 4.71$, $P < 0.05$) for males among months (August to March). Data for months other than October and November are insufficient for a similar analysis for females. The size of male testes is comparatively larger during August (from 22nd to November (combined testes length / SVL = 0.105, \pm 0.0023) and declines from December to March (0.075, \pm 0.0032). Combined fat body length as a ratio of SVL declines from 0.43 (\pm se 0.019) for male *V. tristis* in August and September to 0.32 (\pm 0.023) in October, 0.31 (\pm 0.034) in November to 0.16 (\pm 0.011) in December. It then increases from January (0.28, \pm 0.047) through to February and March (0.34, \pm 0.034). The size of fat bodies in August and September suggests that male *V. tristis* are foraging during autumn and possibly winter. In females, fat bodies during late summer seem to be a similar size to those prior to the breeding season, although late summer data are limited (Fig 3).

The intra-specific allometric relationship between clutch size and body mass and SVL is represented by the following two equations:

$$\text{Clutch size} = 2.6 (\pm 1.73) + 0.035 (\pm 0.0082) \text{ mass (g)}$$

$$(r^2 = 0.43, F_{1,21} = 18.33, P < 0.05), \text{ and}$$

$$\text{Clutch size} = -9.0 (\pm 6.03) + 0.076 (\pm 0.0244) \text{ SVL (mm)}$$

$$(r^2 = 0.28, F_{1,21} = 9.76, P < 0.05).$$

The relationship between SVL and clutch size for ovarian and oviductal eggs is shown in Fig 4.

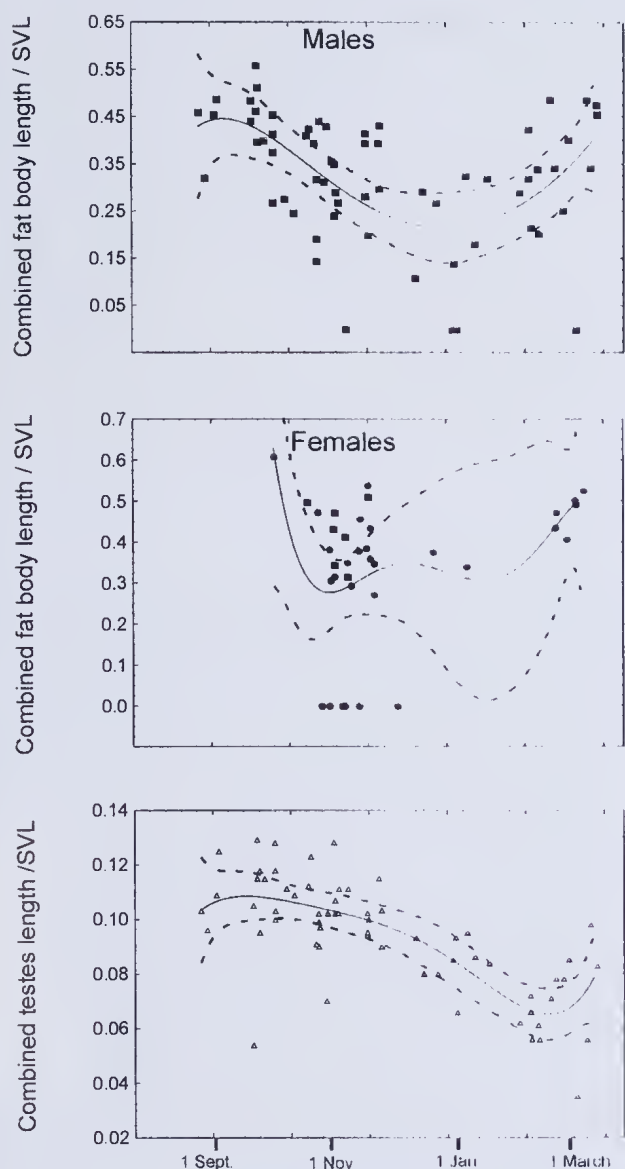


Figure 3. Changes in the size of fat bodies and testes for *V. tristis* over the year. Values are the ratio of combined fat body length/SVL, or combined testes length/SVL. Solid curved lines represent the best-fit polynomial equations; the dotted lines indicate the 95% confidence limits.

Discussion

Movements and locations of male *V. tristis* were dominated by their proximity to females during the breeding season. During the mating season, males spent most time in a tree hollow directly behind a female or moving between a couple of females within their activity area (Thompson *et al.* in press). Male *V. tristis* that had located a female positioned themselves behind the female in a tree hollow, perhaps to block her exit. This is possibly a strategy to stop the female moving to another site and perhaps mating with another male, or alternatively to limit access of other males to the female while she is in the tree. *Varanus tristis* appears to be polygamous, since most males visited at least two females in their activity area (Thompson *et al.* in press).

Tracks indicated that males moved in a direct line between females rather than returning to a female's last known location. Spoor, presumably of a male, was observed to change direction abruptly to follow the spoor of another *V. tristis* (presumably a female; see Tsellarius and Men'shikov 1994) on numerous occasions. *Varanus tristis* spoor often indicated that one *V. tristis* had followed another for distances up to 100 m. Tracks of the second *V. tristis* were always almost directly on top of the first. One male *V. tristis* was observed to travel 723 m in an almost direct line in one day, into the wind, and was found the next day in a dead upright tree with a female (Thompson *et al.* in press). Male *V. tristis* probably follow scent trails carried by the wind to find females.

Our observations on digging and egg laying activity suggest that females oviposited from mid to late October. This is earlier than reported by Pianka (1982) for 11 other *V. tristis* captured during 1978 and 1989 at the same and another site approximately 130 km west (Pianka's L area 28° 31' S, 122° 46' E). Different environmental conditions in 1995 may have advanced the breeding season, or alternatively other unmonitored *V. tristis* may have oviposited later in 1995. To find a possible climatic variable that may have advanced the breeding season for *V. tristis* in 1995, a comparison of minimum and maximum daily temperatures, and total rainfall for the three months preceding oviposition (July, August and September) at Yamarna (8 km west of the study site) indicates a significantly higher maximum daily temperature for both July and August in 1995 compared with 1978 and 1989 (Table 1). These higher maximal temperatures may have resulted in an early emergence of *V. tristis* from their winter inactive retreats and thus brought forward the breeding season.

There are no reports of *V. tristis* normally frequenting or digging holes in the ground, although they have been reported to hide under concrete slabs and water tanks (Christian 1981; Brunn 1982). Similarly, no data have ever previously been reported on nesting sites for this species of goanna. Pit-trapping in the area by Pianka (1994) during late February and early March in 1991 resulted in the capture of only one neonate (72 mm SVL) on 3 March 1991. The early-to-mid February hatching of *V. tristis* eggs laid in mid October is comparable to the

Table 1

Minimum, maximum temperatures and rainfall for Yamarna in July, August and September, 1978, 1989 and 1995.

Variables	1978	1989	1995	P value
July				
Minimum (mean °C)	6.6	2.9	4.2	< 0.05
Maximum (mean °C)	16.9	16.9	19.2	< 0.05
Rain (total mm)	16.0	8.6	20.1	0.56
August				
Minimum (mean °C)	7.6	4.7	5.3	< 0.05
Maximum (mean °C)	19.4	20.1	23.5	< 0.05
Rain (total mm)	46.4	0.0	0.0	< 0.05
September				
Minimum (mean °C)	8.0	9.0	8.9	0.44
Maximum (mean °C)	21.9	26.0	26.5	< 0.05
Rain (total mm)	13.4	0.0	5.0	0.16

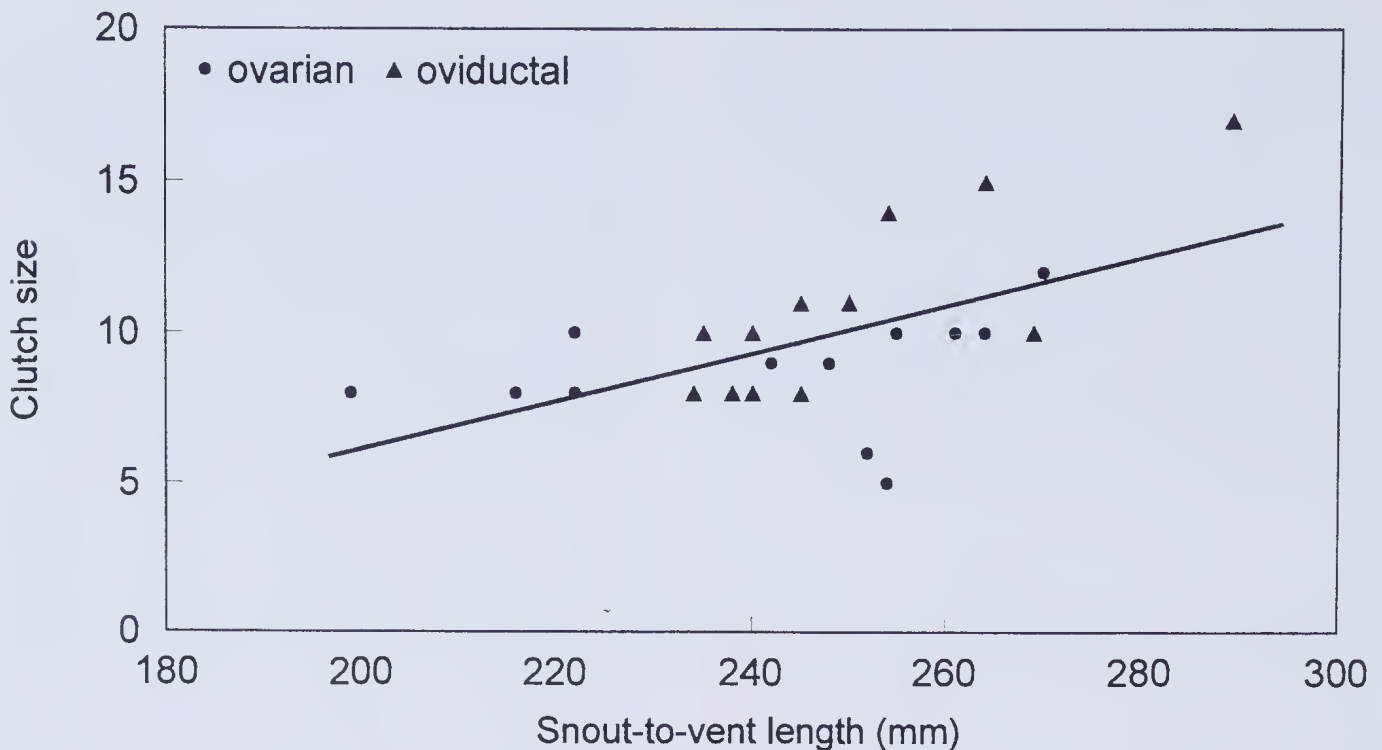


Figure 4. Relationship between the number of ovarian and oviductal eggs and SVL for *V. tristis*. The line is for all points; the equation is $CS = 8.98 + 0.76 SVL$ (mm).

incubation time for other similar-sized monitor lizards (Horn & Visser 1989, 1997). Eidenmüller (1989) reports the incubation time for *V. tristis orientalis* eggs to be between 116 - 136 days at a temperature of $27.5 \text{ }^\circ\text{C}$ ($\pm 0.5 \text{ }^\circ\text{C}$). Therefore eggs laid in November (Pianka 1982, 1994) would probably hatch in March. Adult *V. tristis* are very seasonal in their movement with the majority being seen and tracked in October and November (Pianka 1994). Movement drops off abruptly in December and January, as judged by the presence or absence of tracks. Whether hatchlings remain active during their first winter, or whether they gather sufficient resources during later months of summer to sustain them over a cold winter period of inactivity is unknown. However, a 9 g juvenile was captured in the Perth area foraging in July and captive neonates hatched from eggs taken from this study site were active on warm winter days in an outdoor cage. Three arboreal odatrian goannas from central Western Australia, *V. caudolineatus*, *V. gilleni* and *V. tristis*, all oviposit in Spring (*V. gilleni* 28 October and 1 November - Thompson, unpublished observations, and James *et al.* 1992; *V. caudolineatus* 22 September and 12 October - Thompson, unpublished observations; *V. tristis* 21 October - this study, late November - Pianka 1982). Based on the summary of Horn and Visser (1989, 1997), all three species would hatch towards the end of summer.

The greater length of fat bodies in *V. tristis* in spring compared with late summer suggest that they forage and deposit fat during autumn and winter. The relatively shorter length of fat bodies of females during October to December probably reflects their energy contribution to the production of eggs. Thus, females appear to rely on fat reserves accumulated during the previous summer and autumn as the principle energy source for their clutch. The decline in the male's fat body size during the

breeding season is probably due to their preoccupation with mating rather than feeding. During the breeding season (August - November), testes are comparatively larger. Testes decrease in size from December to a low in March (Fig 3). We have no data on when testes size begins to increase.

Clutch size for *V. tristis* can best be predicted from body mass [$CS = 2.6 + 0.035 \text{ mass (g)}$]. Comparable intra-specific regression equation data to predict clutch mass from SVL or body mass for other varanids are not available. The clutch size of 10 for the female that we monitored laying eggs agrees with the predicted clutch size based on body mass (210 g) but is greater, by one, than the that predicted from SVL (235 mm). Figure 4 shows the variation in clutch size at any particular SVL.

Based on the inter-specific regression equation of James *et al.* (1992) for Australian *Varanus* spp, clutch size = $0.03 SVL^{1.01}$ (without *V. semiremex*, *V. giganteus*, *V. varius*) an average female *V. tristis* with a 235 mm SVL would be expected to have a mean clutch size of about 7.4 eggs. This is appreciably below the mean for this species of 9.8; only two of the 24 gravid female *V. tristis* examined had a clutch of 7 or less eggs. However, if only the Odatrian data from James *et al.* (1992) are included in the regression equation, clutch size = $0.004 SVL^{1.44}$ ($r^2 = 0.9$; Fig 5) and the predicted clutch size for *V. tristis* is 10.4, closer to the actual species mean. Thus, the relationship between body length and clutch size could differ between the two subgenera (*Odatria* and *Varanus*).

The significance of the white powder stain on the dorsal surface of the lower back and pelvic area of females (Fig 1) is unknown and merits further investigation. One likely explanation is that it is uric acid rubbed on the female by the male prior to mating.

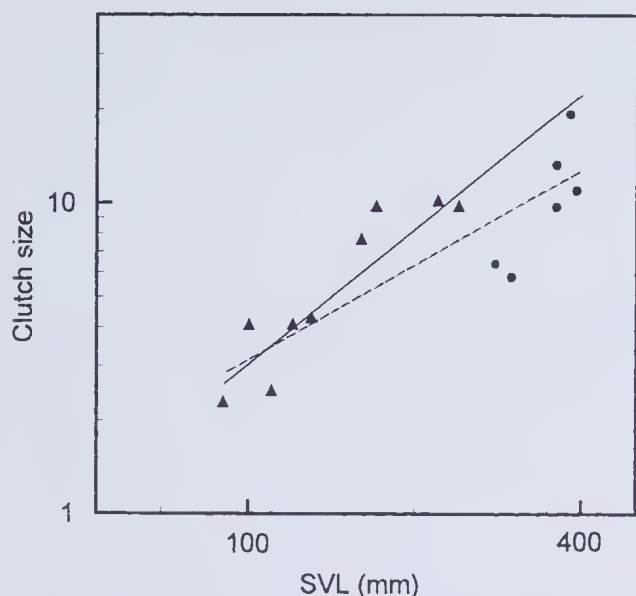


Figure 5. Relationship between snout-to-vent length and clutch size for varanids (from James *et al.* 1992), with regression lines for all species (dotted, James *et al.* 1992) compared with the regression line for odatrian (solid line; triangles) goannas.

The body surface colour and pattern of neonate *V. t. tristis* in the western Great Victoria Desert differs from that of *V. t. orientalis*, which have a pattern very similar to adults. Neonate varanids often are more colourful than adults (King and Green 1993). Why the pattern only persists for a couple of months is unknown.

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